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Numerical Studies of Collisionless Current Layers

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Final Report

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The purpose of this proposal was to investigate collisionless current layers using a variety of analytical and numerical tools. The first year of the contract was dedicated to analytical studies, to the porting and adaption of codes being used in this study, and to the numerical simulation of collisionless current layers. The second year entailed the development of multi-dimensional hybrid algorithms as well as the re-examination of the problem of integro-differential equations that occur in the linear stage of plasma instabilities.

A recurring problem in reconnection is the physical mechanism that allows field lines to diffuse through the neutral layer of a magnetic field-reversed plasma. Since plasmas in space are collisionless, numerous models have been proposed that use the inertia of the electrons (or the ions) as a replacement for resistivity in Ohm's Law. This procedure, however, is not correct. We completed (in the first year) an investigation of the importance of inertial effects in reconnection, and showed analytically that electron (or ion) acceleration without dissipation cannot generate reconnection in a quasi-neutral two-fluid with isotropic pressures. This result is general, and follows from the conservation of the canonical vorticity in isentropic magnetofluids. When dissipative processes such as Landau damping are allowed, however, reconnection becomes possible and proceeds at rate controlled by the extent of the diffusion region divided by the ion inertial length. These results have been written up and (re)submitted to the Journal of Geophysical Research (Quest and Brackbill, 1990).

During the last year of the proposal we concentrated on developing a two-dimensional hybrid capability for reconnection in a collisionless plasma with applications to tearing and the Kelvin Helmholtz and tearing instabilities. Certain boundary condition and energy conservation issues proved more difficult to deal with than anticipated, and we hope to soon begin the actual simulations in the very near future. We also achieved some progress in the related issue of how to treat linear eigenvalue problems such as tearing in the

magnetotail. Such geometries result in integro-differential equations that are quite difficult to solve analytically. This is particularly the case when dealing with kinetic effects (and the associated integrals) such as electron and ion Landau resonances. We have developed a new method for handling such calculations that evaluates the integral portion of the problem uses PIC techniques similar to those employed in standard simulation codes. There results are large set of coupled equations for the vector potential (or electrostatic potential) that can be solved by iterative matrix schemes, yielding the desired growth rates and frequencies of the instabilities. Preliminary results show good agreement with earlier, more approximate calculations. We are now applying this technique to tearing in the magnetotail with realistic field geometries, to the problem of the linear evolution of the (kinetic) Kelvin Helmholtz, and will shortly begin an application to tearing at the dayside magnetopause. These results will all be presented at the upcoming Spring AGU meeting.

PAPERS

1. Quest, K. B., and J. U. Brackbill, Consequences of electron inertia of fluid models of reconnection, resubmitted to J. Geophys. Res., 1992.